Claims

What is claimed is:

1. A mixer circuit for generating an IF output responsive to an RF input and a LO drive source, comprising:

a mixer core having a doubly balanced mixer including a first differentially coupled transistor pair and a second differentially coupled transistor pair;

an RF input circuit coupled to the mixer core, the RF input circuit comprising:

an input inductor having a first terminal coupled to receive an RF input signal and a second terminal;

a biasing resistor having a first terminal coupled to the second terminal of the input inductor and a second terminal coupled to a first bias voltage;

a first input transistor having a control terminal coupled to the second terminal of the input inductor, a second terminal, and a third terminal;

a second inductor having a first terminal coupled to the second terminal of the first input transistor and to the first differentially coupled transistor pair, the second inductor also having a second terminal coupled to a ground potential;

a supply resistor having a first terminal coupled to the second terminal of the first input transistor and a second terminal coupled to a supply potential;

a first capacitor having a first terminal also coupled to the second terminal of the first input transistor and a second terminal coupled to the second differentially coupled transistor pair; and

a third inductor having a first terminal coupled to the second terminal of the first capacitor and a second terminal coupled to the ground potential.

2. The mixer circuit according to Claim 1 wherein the first differentially coupled transistor pair, the second differentially coupled transistor pair and the first input transistor are all npn transistors.

3. The mixer circuit according to Claim 1 wherein the first differentially coupled transistor pair, the second differentially coupled transistor pair and the first input transistor are all pnp transistors.

4. The mixer circuit according to Claim 1 wherein the first differentially coupled transistor pair, the second differentially coupled transistor pair and the first input transistor are all MOSFET transistors.

5. The mixer circuit according to Claim 1 wherein the first differentially coupled transistor pair, the second differentially coupled transistor pair and the first input transistor are all MESFET transistors.

6. A mixer circuit for generating an IF output responsive to an RF input and a LO drive source, comprising:

a mixer core having a doubly balanced mixer including a first differentially coupled npn transistor pair and a second differentially coupled npn transistor pair, the mixer core coupled to receive a LO drive signal, the LO drive signal having a plurality of harmonics;

a low noise RF input circuit coupled to the mixer core through a cascode circuit, the low noise RF input circuit coupled to receive an RF input signal, wherein the cascode circuit further isolates the RF input circuit from the LO drive signal and the plurality of harmonics.

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7. A mixer as in Claim 6 wherein the cascode circuit comprises:

a first cascode transistor having an emitter terminal coupled to the second terminal of the first capacitor and to the first terminal of the third inductor, a collector terminal coupled to the second differentially coupled npn transistor pair and a base terminal,

a second cascode transistor having a base terminal coupled to the base terminal of the first cascode transistor, an emitter terminal coupled to the first terminal of the second inductor and to the emitter terminal of the first npn transistor and a collector terminal coupled to the first differentially coupled npn transistor pair,

a second capacitor, having a first terminal coupled to the collector terminal of the first cascode transistor and a second terminal coupled to the base terminal of the first cascode transistor and to the base terminal of the second cascode transistor,

a third capacitor, having a first terminal coupled to the emitter terminal of the second cascode transistor and a second terminal coupled to the second terminal of the second capacitor and to the base terminal of the first cascode transistor and to the base terminal of the first cascode transistor,

a second biasing resistor having a first terminal coupled to the second terminal of the third capacitor and a second terminal coupled to a second bias voltage.

8. A mixer as in Claim 7, wherein the low noise RF input circuit further includes a RF feedback circuit, the RF feedback circuit comprising:

a second npn transistor having a base terminal coupled to the supply potential, an emitter terminal coupled to the collector terminal of the first input npn transistor and a collector terminal coupled to the first terminal of the supply resistor and to the first terminal of the first capacitor,

a feedback resistor, having a first terminal coupled to the base terminal of the first input npn transistor and a second terminal,

a second capacitor, having a first terminal coupled to the second terminal of the feedback resistor and a second terminal coupled to the first terminal of the supply resistor.

9. A mixer as in Claim 7, wherein the mixer core further includes a tracking supply circuit, the tracking supply circuit comprising:

a first diode-connected transistor having a cathode terminal coupled to the ground potential and an anode terminal,

a second diode-connected transistor having a cathode terminal coupled to the anode terminal of the first diode connected transistor and an anode terminal,

a third resistor having a first terminal coupled to the anode terminal of the second diode connected transistor and a second terminal,

a first current supply having a first terminal coupled to the second terminal of the third resistor and a second terminal coupled to the supply potential,

a loop amplifier having a first terminal coupled to the second terminal of the third resistor and to the first terminal of the first current supply, a second terminal coupled to the supply potential, a third terminal coupled to the ground potential and a fourth terminal,

a fourth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal,

a second npn transistor having a collector terminal coupled to the second terminal of the fourth resistor, a base terminal coupled to receive a first LO drive signal and emitter terminal,

a third npn transistor having a base terminal coupled to receive a second LO drive signal, an emitter terminal coupled to the emitter terminal of the second npn transistor and a collector terminal,

a fifth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal coupled to the collector terminal of the third npn transistor

a second current supply having a first terminal coupled to the emitter terminal of the second npn transistor and to the emitter terminal of the third npn transistor and a second terminal coupled to the ground potential,

a first common collector amplifier having a base terminal coupled to the second terminal of the fifth resistor and to the collector terminal of the third npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier, and an emitter terminal coupled to a first mixer core LO input,

a third current supply having a first terminal coupled to the emitter terminal of the first common collector amplifier and a second terminal coupled to the ground potential,

a second common collector amplifier having a base terminal coupled to the second terminal of the fourth resistor and to the collector terminal of the second npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier and an emitter terminal coupled to a second mixer core LO input,

a fourth current supply having a first terminal coupled to the emitter terminal of the second common collector amplifier and a second terminal coupled to the ground potential.

10. A mixer as in Claim 7, wherein the low noise RF input circuit further includes a

tracking mixer bias current circuit coupled to the second bias input terminal, the tracking mixer bias current circuit comprising:

a third resistor having a first terminal coupled to the supply potential and a second terminal,

a first diode connected transistor having a anode terminal coupled to the second terminal of the third resistor and a cathode terminal,

a second npn transistor having a collector terminal coupled to the cathode terminal of the first diode connected transistor, an emitter terminal coupled to the ground potential and a base terminal,

a loop amplifier having a first terminal coupled to the emitter terminal of the first diode connected transistor and to the collector terminal of the second npn transistor, a second terminal coupled to the second bias voltage and a third terminal,

a fourth resistor having a first terminal coupled to the base terminal of the second npn transistor and a second terminal coupled to the second terminal of the loop amplifier and to the second bias voltage,

a bandgap voltage supply having a first terminal coupled to the ground potential and a second terminal coupled to the third terminal of the loop amplifier.

11. A mixer circuit as in Claim 6, wherein the mixer core further includes a tracking supply circuit, the tracking supply circuit comprising:

a first diode-connected transistor having a cathode terminal coupled to the ground potential and an anode terminal,

a second diode-connected transistor having a cathode terminal coupled to the anode terminal of the first diode connected transistor and an anode terminal,

a third resistor having a first terminal coupled to the anode terminal of the second diode connected transistor and a second terminal,

a first current supply having a first terminal coupled to the second terminal of the third resistor and a second terminal coupled to the supply potential,

a loop amplifier having a first terminal coupled to the second terminal of the third resistor and to the first terminal of the first current supply, a second terminal coupled to the supply potential, a third terminal coupled to the ground potential and a fourth terminal,

a fourth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal,

a second npn transistor having a collector terminal coupled to the second terminal of the fourth resistor, a base terminal coupled to receive a first LO drive signal and emitter terminal,

a third npn transistor having a base terminal coupled to receive a second LO drive signal, an emitter terminal coupled to the emitter terminal of the second npn transistor and a collector terminal,

a fifth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal coupled to the collector terminal of the third npn transistor

a second current supply having a first terminal coupled to the emitter terminal of the second npn transistor and to the emitter terminal of the third npn transistor and a second terminal coupled to the ground potential,

a first common collector amplifier having a base terminal coupled to the second terminal of the fifth resistor and to the collector terminal of the third npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier, and an emitter terminal coupled to a first mixer core LO input,

a third current supply having a first terminal coupled to the emitter terminal of the first common collector amplifier and a second terminal coupled to the ground potential,

a second common collector amplifier having a base terminal coupled to the second terminal of the fourth resistor and to the collector terminal of the second npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier and an emitter terminal coupled to a second mixer core LO input,

a fourth current supply having a first terminal coupled to the emitter terminal of the second common collector amplifier and a second terminal coupled to the ground potential.

12. A mixer circuit as in Claim 6, wherein the low noise RF input circuit further includes a RF feedback circuit coupled to the RF input circuit, the RF feedback circuit comprising:

a second npn transistor having a base terminal coupled to the supply potential, an emitter terminal coupled to the collector terminal of the first input npn transistor and a collector terminal coupled to the first terminal of the supply resistor and to the first terminal of the first capacitor,

a feedback resistor, having a first terminal coupled to the base terminal of the first input npn transistor and a second terminal,

a second capacitor, having a first terminal coupled to the second terminal of the feedback resistor and a second terminal coupled to the first terminal of the supply resistor.

13. A quadrature mixer circuit for generating a quadrature IF output responsive to an RF input and a quadrature pair of LO drive signals, comprising:

a mixer core having a first doubly balanced mixer including a first differentially coupled npn transistor pair and a second differentially coupled npn transistor pair and a second doubly balanced mixer including a third differentially coupled npn transistor pair and a fourth differentially coupled npn transistor pair;

an RF input circuit coupled to the mixer core, the RF input circuit comprising:

an input inductor having a first terminal coupled to receive an RF input signal and a second terminal;

a biasing resistor having a first terminal coupled to the second terminal of the input inductor and a second terminal coupled to a first bias voltage;

a first input npn transistor having a base terminal coupled to the second terminal of the input inductor, an emitter terminal, and a collector terminal;

a second inductor having a first terminal coupled to the emitter of the first npn transistor and to the first differentially coupled npn transistor pair and to the third differentially

coupled npn transistor pair, the second inductor also having a second terminal coupled to a ground potential;

a supply resistor having a first terminal coupled to the collector of the first transistor and a second terminal coupled to a supply potential;

a first capacitor having a first terminal also coupled to the collector of the first transistor and a second terminal coupled to the second differentially coupled npn transistor pair and to the fourth differentially coupled npn transistor pair; and

a third inductor having a first terminal coupled to the second terminal of the first capacitor and a second terminal coupled to the ground potential.

14. A quadrature mixer circuit for generating a quadrature IF output responsive to an RF input and a quadrature pair of LO drive signals, comprising:

a mixer core having a first doubly balanced mixer including a first differentially coupled npn transistor pair and a second differentially coupled npn transistor pair and having a second doubly balanced mixer including a third differentially coupled npn transistor pair and a fourth differentially coupled npn transistor pair; the mixer core coupled to receive a quadrature LO drive signal, the quadrature LO drive signal having a plurality of harmonics;

a low noise RF input circuit coupled to the mixer core through a cascode circuit, the low noise RF input circuit coupled to receive an RF input signal, wherein the cascode circuit further isolates the RF input circuit from the quadrature LO drive signal and the plurality of harmonics.

15. A quadrature mixer as in Claim 14 wherein the cascode circuit comprises:

a first cascode transistor having an emitter terminal coupled to the second terminal of the first capacitor and to the first terminal of the third inductor, a collector terminal coupled to the second differentially coupled npn transistor pair and a base terminal,

a second cascode transistor having a base terminal coupled to the base terminal of the first cascode transistor, an emitter terminal coupled to the first terminal of the second inductor and to the emitter terminal of the first npn transistor and a collector terminal coupled to the first differentially coupled npn transistor pair,

a second capacitor, having a first terminal coupled to the collector terminal of the first cascode transistor and a second terminal coupled to the base terminal of the first cascode transistor and to the base terminal of the second cascode transistor,

a third capacitor, having a first terminal coupled to the emitter terminal of the second cascode transistor and a second terminal coupled to the second terminal of the second capacitor and to the base terminal of the first cascode transistor and to the base terminal of the first cascode transistor,

a second biasing resistor having a first terminal coupled to the second terminal of the second capacitor and the first terminal of the third capacitor and a second terminal coupled to a second bias voltage,

a third biasing resistor having a first terminal coupled to the second bias voltage and to the second terminal of the second biasing resistor and having a second terminal,

a third cascode transistor having a collector terminal coupled to the fourth differentially coupled npn transistor pair, an emitter terminal coupled to the second terminal of the third inductor and to the emitter terminal of the first cascode transistor, and a base terminal,

a fourth cascode transistor having a base terminal coupled to the base terminal of the third cascode transistor, a collector terminal coupled the third differentially coupled npn transistor pair and an emitter terminal coupled to the emitter terminal of the second cascode transistor and to the second terminal of the second inductor,

a fourth capacitor having a first terminal coupled to the emitter terminal of the third cascode transistor and a second terminal coupled to the base terminal of the third and fourth cascode transistors,

a fifth capacitor having a first terminal coupled to the second terminal of the fourth capacitor and to the base terminals of the third and fourth cascode transistors and a second terminal coupled to the emitter terminal of the fourth cascode transistor.

16. A quadrature mixer as in Claim 15 wherein the low noise RF input circuit further includes a RF feedback circuit, the RF feedback circuit comprising:

a second npn transistor having a base terminal coupled to the supply potential, an emitter terminal coupled to the collector terminal of the first input npn transistor and a collector terminal coupled to the first terminal of the supply resistor and to the first terminal of the first capacitor,

a feedback resistor, having a first terminal coupled to the base terminal of the first input npn transistor and a second terminal,

a sixth capacitor, having a first terminal coupled to the second terminal of the feedback resistor and a second terminal coupled to the first terminal of the supply resistor.

17. A quadrature mixer as in Claim 16, wherein the mixer core further includes a first tracking supply circuit portion coupled to the In-Phase LO drive input terminals of the mixer core and a second tracking supply circuit portion coupled to the Quadrature Phase LO drive input terminals of the mixer core.

18. A mixer circuit as in Claim 17, wherein the first tracking supply comprises:

a. a first diode-connected transistor having a cathode terminal coupled to the ground potential and an anode terminal;

b. a second diode-connected transistor having a cathode terminal coupled to the anode terminal of the first diode connected transistor and an anode terminal,

c. a third resistor having a first terminal coupled to the anode terminal of the second diode connected transistor and a second terminal;

d. a first current supply having a first terminal coupled to the second terminal of the third resistor and a second terminal coupled to the supply potential;

e. a loop amplifier having a first terminal coupled to the second terminal of the third resistor and to the first terminal of the first current supply, a second terminal

coupled to the supply potential, a third terminal coupled to the ground potential and a fourth terminal;

f. a fourth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal;

g. a second npn transistor having a collector terminal coupled to the second terminal of the fourth resistor, a base terminal coupled to receive a first LO drive signal and emitter terminal;

h. a third npn transistor having a base terminal coupled to receive a second LO drive signal, an emitter terminal coupled to the emitter terminal of the second npn transistor and a collector terminal;

i. a fifth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal coupled to the collector terminal of the third npn transistor;

j. a second current supply having a first terminal coupled to the emitter terminal of the second npn transistor and to the emitter terminal of the third npn transistor and a second terminal coupled to the ground potential;

k. a first common collector amplifier having a base terminal coupled to the second terminal of the fifth resistor and to the collector terminal of the third npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier, and an emitter terminal coupled to a first mixer core LO input;

l. a third current supply having a first terminal coupled to the emitter terminal of the first common collector amplifier and a second terminal coupled to the ground potential;

m. a second common collector amplifier having a base terminal coupled to the second terminal of the fourth resistor and to the collector terminal of the second npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier and an emitter terminal coupled to a second mixer core LO input; and

n. a fourth current supply having a first terminal coupled to the emitter terminal of the second common collector amplifier and a second terminal coupled to the ground potential;

and wherein the second tracking supply circuit portion comprises:

o. a third diode-connected transistor having a cathode terminal coupled to the ground potential and an anode terminal;

p. a fourth diode-connected transistor having a cathode terminal coupled to the anode terminal of the third diode connected transistor and an anode terminal;

q. a third resistor having a first terminal coupled to the anode terminal of the second diode connected transistor and a second terminal;

r. a first current supply having a first terminal coupled to the second terminal of the third resistor and a second terminal coupled to the supply potential;

s. a loop amplifier having a first terminal coupled to the second terminal of the third resistor and to the first terminal of the first current supply, a second terminal coupled to the supply potential, a third terminal coupled to the ground potential and a fourth terminal;

t. a fourth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal;

u. a second npn transistor having a collector terminal coupled to the second terminal of the fourth resistor, a base terminal coupled to receive a first LO drive signal and emitter terminal;

v. a third npn transistor having a base terminal coupled to receive a second LO drive signal, an emitter terminal coupled to the emitter terminal of the second npn transistor and a collector terminal;

w. a fifth resistor having a first terminal coupled to the fourth terminal of the loop amplifier and a second terminal coupled to the collector terminal of the third npn transistor;

x. a second current supply having a first terminal coupled to the emitter terminal of the second npn transistor and to the emitter terminal of the third npn transistor and a second terminal coupled to the ground potential;

y. a first common collector amplifier having a base terminal coupled to the second terminal of the fifth resistor and to the collector terminal of the third npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier, and an emitter terminal coupled to a first mixer core LO input;

z. a third current supply having a first terminal coupled to the emitter terminal of the first common collector amplifier and a second terminal coupled to the ground potential;

aa. a second common collector amplifier having a base terminal coupled to the second terminal of the fourth resistor and to the collector terminal of the second npn transistor, a collector terminal coupled to the fourth terminal of the loop amplifier and an emitter terminal coupled to a second mixer core LO input;

bb. a fourth current supply having a first terminal coupled to the emitter terminal of the second common collector amplifier and a second terminal coupled to the ground potential.

19. A quadrature mixer as in Claim 15, wherein the low noise RF input circuit further includes a tracking mixer bias current circuit, the tracking bias current circuit comprising:

a first resistor having a first terminal coupled to the supply potential and a second terminal,

a first diode connected transistor having a anode terminal coupled to the second terminal of the third resistor and a cathode terminal,

a second npn transistor having a collector terminal coupled to the cathode terminal of the first diode connected transistor, an emitter terminal coupled to the ground potential and a base terminal,

a loop amplifier having a first terminal coupled to the emitter terminal of the first diode connected transistor and to the collector terminal of the second npn transistor, a second terminal coupled to the second bias voltage and a third terminal,

a second resistor having a first terminal coupled to the base terminal of the second npn transistor and a second terminal coupled to the second terminal of the loop amplifier and to the second bias voltage,

a bandgap voltage supply having a first terminal coupled to the ground potential and a second terminal coupled to the third terminal of the loop amplifier.

20. A mixer circuit for generating an IF output responsive to an RF input and a LO drive source, comprising:

a mixer core having a doubly balanced mixer including a first differentially coupled npn transistor pair and a second differentially coupled npn transistor pair;

a single ended RF input circuit coupled to receive an RF signal, the RF circuit coupled to the mixer core, the RF circuit including means for providing an input impedance, means for splitting a phase of the RF signal, and means for decoupling noise from the RF signal to the mixer core.

21. A mixer circuit for generating an IF output responsive to an RF input and a LO drive source, comprising:

a mixer core having a doubly balanced mixer including a first differentially coupled npn transistor pair and a second differentially coupled npn transistor pair, the mixer core coupled to receive a LO drive signal, the LO drive signal having a plurality of harmonics;

a low noise single ended RF input circuit coupled to the mixer core through a cascode circuit, the low noise RF input circuit coupled to receive an RF input signal, wherein the cascode circuit further isolates the RF input circuit from the LO drive signal and the plurality of harmonics the RF circuit including means for providing an input impedance and means for splitting a phase of the RF signal.